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AMS-02 AND ITS POTENTIAL IN THE SEARCH FOR DARK MATTER

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This article gives a description of the AMS-02 detector, focussing on the objective of indirect searches for Dark Matter.

1. Introduction

The Alpha Magnetic Spectrometer, AMS-02, is a high-energy physics type of detector, scheduled for a 3 year mission on board the International Space Station. The physics goals of AMS are to search for anti-matter in cosmic-rays with a sensitivity at the level of 10^{-9} , to make high statistics measurements of the composition of charged cosmic-rays, as well as gamma-rays in the GeV to TeV energy range, and to search indirectly for the neutralino, a candidate for Dark Matter.

2. Neutralino as DM candidates

The presence in our universe of non-baryonic Dark Matter is now well established ¹, with a contribution ranging between 0.1 and 0.3 of the total energy density Ω . The neutralino, arising in Super-Symmetric models as a linear combination of the super partners of the gauge and Higgs bosons is a viable candidate for Dark Matter. In several models where R-parity is conserved, the neutralino is the lightest super-symmetric particle and is stable.

The neutralino could then be detected through the decay products of its annihilation in the galactic halo, leading to an additional spectrum of either charged particles, p , \bar{p} , e^+ , e^- , D , \bar{D} or γ 's. Due to the larger background of matter in cosmic-rays, such as protons and electrons, experimentally, the search will be oriented toward anti-matter such as \bar{p} , e^+ , \bar{D} and γ 's.

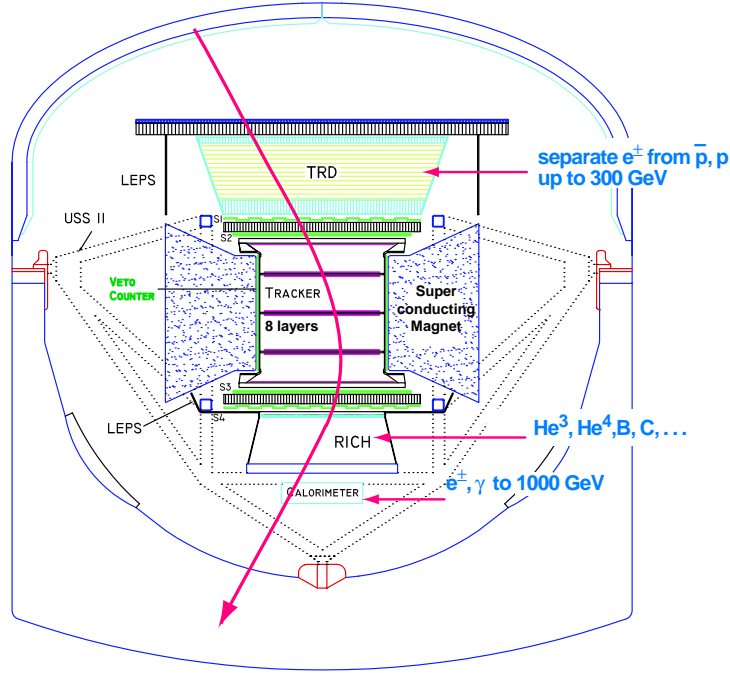


Figure 1. Schematic of AMS-02 detector.

Therefore it is essential to determine the charge of the particles and to obtain a rejection against the proton background of, e.g., at least 10^4 at 200 GeV. A good energy resolution is helpful to identify a signal on top of an expected background falling as $E^{-\alpha}$ where $\alpha = 2.7$ to 3.. Identifying photons provides a complementary channel.

3. The AMS-02 detector

AMS-02 is designed to meet these goals as will be seen in the following subsections. A schematic of the detector is presented in figure 1. The overall detector acceptance is of the order of $0.6 \text{ m}^2 \cdot \text{sr}$, but using the calorimeter reduces it by a factor 10.

3.1. *The silicon tracker*

The silicon tracker is inserted in a magnetic field of 0.86 T, created by a super-conducting magnet. It is made of 5 planes of silicon microstrip detectors, the 3 central ones being double-sided. The total surface of silicon is 6 m². The position resolution in the bending plane is 10 μ m.

The silicon tracker is designed to measure particle rigidity with a precision better than 15% up for hadronic particles up to TV. The resolution is 2% at 1 GV. It also provides a measurement of β for particles with momentum less than 1.5 GeV, through dE/dx deposition in silicon. Finally, it can reconstruct converted gammas in the range 2 to 200 GeV with an energy resolution of $\sigma_E/E = 0.025 \oplus 5.10^{-4} \times \sqrt{E}$ (GeV) and an angular resolution of $0.018 \text{ deg} \oplus 0.85 \text{ deg}/E^2$.

3.2. *The Time-of-flight detector*

The Time-of-flight system consists of four scintillator planes situated on either side of the tracker. With a time resolution of 150 ps, it determines the direction of the crossing particle with no ambiguity at the level of 10^{-10} . It also provides a dE/dx measurement, and is the main component of the charged first level trigger.

3.3. *The Transition Radiation detector*

Located on top of AMS, the transition radiation detector (TRD) is designed to separate protons from positrons. It consists of 20 layers of fleece and 6 mm diameter straw-tubes filled with Xe/CO₂. Its main aim is to obtain a proton rejection factor of 1000 at 2 GeV and of 100 at 200 GeV while maintaining the positron/electron efficiency at 90%. It also provides 20 additional tracking points.

3.4. *The calorimeter*

The calorimeter consists of 9 layers of lead and embedded scintillating fibres, with a thickness of 18 mm each. Layers are oriented alternatively along the x or y directions. The signal is read by 4-anode PMTs giving a granularity of 18 samplings in depth and 0.5 Molière radius in x or y . Due to this high granularity, a hadron rejection factor of the order of 10^3 is expected from MC simulation. With a total number of 16 radiation lengths, the energy of electromagnetic particles is measured with a resolution of $\sigma(E)/E = 0.03 \oplus 0.13/\sqrt{E}$ (GeV) up to approximately 2 TeV.

The calorimeter information is used in the positron trigger and in the stand-alone gamma trigger. Gammas in the calorimeter acceptance are reconstructed with an angular resolution of $\sigma(\Omega) = 0.9 \text{ deg} \oplus 8.5 \text{ deg} / \sqrt{E}$.

3.5. *The Ring Imaging Cherenkov detector*

The Ring Imaging Cherenkov detector consists of an aerogel radiator plate with a refractive index 1.05 followed by a drift space. The Cherenkov ring is detected on an array of multi-anode PMTs situated underneath. The velocity β is measured with 0.1% precision.

Associated with the rigidity measurement in the tracker, the RICH will provide an identification of isotopes such as Be^9 and Be^{10} up to an atomic number of 25 for nuclei with momentum less than 15 GeV/N and of chemical elements with Z less or equal 26 for momentum in TeV/N range.

The RICH also provides an additional proton rejection factor for momentum less than 15 GeV, and rejects albedo particles at the level of 10^{-3} .

4. Neutralino indirect signal detection

The search for an indirect signal of neutralino annihilations will be performed in the following channels: positrons, antiprotons, antideuterons and gammas.

4.1. *Positrons*

The AMS-02 acceptance for positrons has been estimated to be $0.15 \text{ m}^2 \cdot \text{sr}$ at 10 GeV and $0.045 \text{ m}^2 \cdot \text{sr}$ at higher energy². Therefore, in 3 years, the positron spectrum will be measured to 300 GeV with a statistical precision better than 1% around 100 GeV and 30% at 300 GeV.

4.2. *Antiprotons and antideuterons*

Recent measurements of the low energy antiprotons spectrum from BESS³ and AMS-01⁴ and recent calculations of the expected secondary antiproton spectrum from conventional origins⁵ are now in agreement. However, the precision of the predictions is only of the order of 25% and an additional SUSY signal cannot be excluded. In figure 2, a simulated measurement of the antiproton spectrum with AMS in 3 years is presented with statistical errors⁶. At high energy, some SUSY models with heavy neutralino⁷ predict sizeable effects in the range accessible with AMS, assuming that there is a clumpy dark halo.⁷

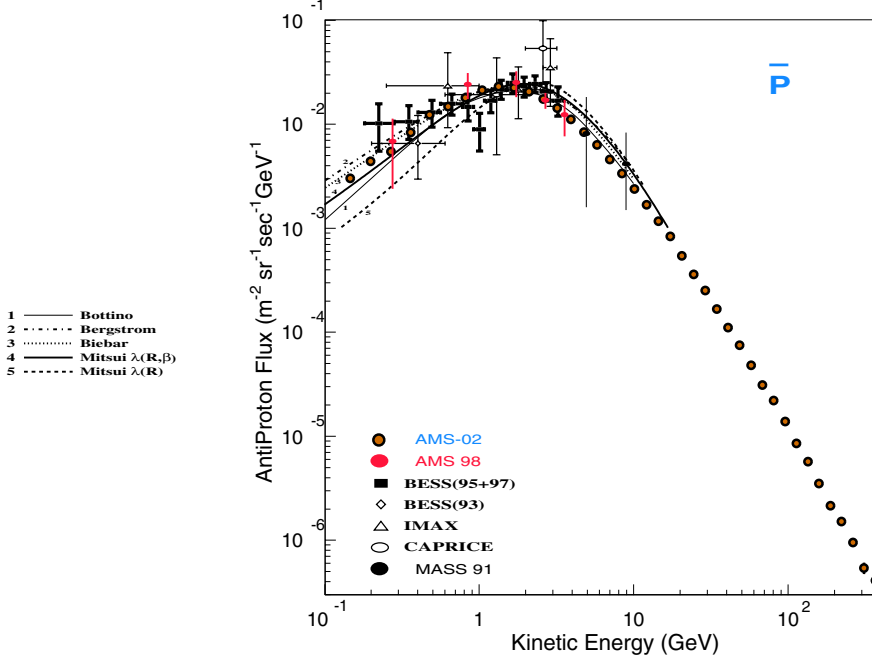


Figure 2. Simulated measurement with statistical errors of antiproton spectrum in AMS in 3 years⁶. Surperimposed are a compilation of antiproton measurements^{3 4} and models³.

At low energy, an appealing alternative lies in the antideuteron spectrum⁸. At energies below 3 GeV/N, secondary antideuterons are suppressed with respect to “primary” antideuterons from supersymmetric origin. In 3 years, AMS could be sensitive to part of the SUSY parameter space.

4.3. Gammas

AMS is mounted on the ISS and is always pointing towards its local vertical. In a year, exposure to the galactic center is $6 \times 10^9 \text{ cm}^2 \cdot \text{s}$ and AMS acceptance is of the order of $0.11 \text{ m}^2 \cdot \text{sr}$ when combining the tracker mode and the calorimeter mode². AMS will be sensitive to the most cuspy models of dark halo, for both the gamma continuum and the resonance channels⁹.

5. Conclusion

Concerning the indirect detection of dark matter, AMS will be able to perform precision measurements of the relevant cosmic-rays spectra. Combining these measurements will increase our sensitivity.

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